

Chapter 4

Strategies for Addressing Water Quality Problems

4.1 Introduction

The purpose of this chapter is to present general information on the types of strategic actions that can be employed to address various water quality problems. ***It should be noted that the chapter is not an all-inclusive list of strategies to address nonpoint or point source problems.*** Many other documents exist for this purpose. The aim of the chapter is to present readers with a framework for categorizing water quality stressors and sources and for considering strategies within each. Select strategies are discussed in each category and some examples are provided to illustrate key points. References to more detailed resources for strategy information are provided throughout the chapter. Additional resources are also provided in Appendix E. Both this chapter and Appendix E emphasize “green” activities—those strategies that will improve water quality and reduce water and/or energy consumption and greenhouse gas emissions

4.2 Background

The term “water quality” refers to the chemical, biological, physical and radiological composition of water as impacted by natural processes and human activities (OSUE 1992). The term is used in relation to both surface and groundwaters. Threats to water quality are both natural and man-made. Human activities can exacerbate the negative effects of natural phenomena. The greatest threats to water quality tend to be due to incompatible land and water uses in the communities adjacent to the waterways (Low 1999).

Pollutants get into water via point or nonpoint sources. Point sources are discrete conveyances of pollutants to a waterbody. They include direct, end-of-pipe discharges from wastewater treatment plants, industries, and commercial facilities.¹ They also include overflows from impoundments or discharges from concentrated animal feeding operations or vessels or other floating craft. The term does not include agricultural return flows from irrigated agriculture. Nonpoint sources are those that do not meet the legal definition of a point source. Nonpoint source pollution occurs when rainwater or snowmelt cause pollutants to be picked up on land and transported to surface waterbodies as part of the hydrologic cycle. Nonpoint source pollution also results from atmospheric deposition, drainage, seepage, or hydrologic modification (USEPA 2010c). Polluted nonpoint runoff can occur in industrial sectors such as mining, agriculture, forestry, water resources management, recreation, transportation, and development.² The term “point sources” tends to get used interchangeably to convey *how* pollutants get into water as well as *who* contributes the pollutants. The same holds true for nonpoint sources as well.

¹ 33 U.S.C. § 1362(14).

² Although diffuse runoff is generally treated as nonpoint source pollution, runoff that enters and is discharged from discrete conveyances such as impoundments, concentrated animal feeding operations, and vessels are treated as a point source discharge and are subject to Clean Water Act National Pollutant Discharge Elimination System permit requirements.

In the early years of Clean Water Act (CWA) implementation up through the mid-to-late 1980s, the U.S. Environmental Protection Agency (EPA) and authorized states focused mainly on controlling point source pollution. Toxic and other pollutants from these sources were considered of utmost importance at the time. From a regulatory standpoint, point sources are easier to address than nonpoint sources because they are more readily identifiable and because similar treatment or operational controls can be applied to broad categories of facilities (i.e., those with similar processes and wastestreams).

In the late 1980s Congress recognized that the nation had made substantial progress in addressing point source pollution but that work remained on controlling nonpoint sources if the goals of the CWA were to be realized. Congress amended the CWA in 1987 to include the section 319 program. This program requires states to develop and implement programs addressing nonpoint sources of pollution.³ See chapter 2, “*Water Quality Planning and Management in Colorado*,” for an explanation of how Colorado has developed and is implementing this program.

Because nonpoint sources are diffuse, they are often difficult to identify. Moreover, there are limited technological solutions that can be applied to control them. They are typically addressed through the application of best management practices (BMPs). BMPs are physical, structural or managerial practices that decrease the potential for a site to contribute polluted runoff to a waterbody. BMPs can be used alone or in combination. The selection, installation and monitoring of BMPs tends to be highly individualized. Generally, BMPs are unenforceable. Some BMPs can be implemented through land use controls, such as zoning and land use planning (ABA 2003).

Colorado’s latest Integrated Report⁴ identified nonpoint sources as the leading cause of water quality problems in the state (WQCC 2010b; WQCD 2010b). EPA has identified these sources as the leading cause of water quality problems nationwide (USEPA 2008).

4.3 The Watershed Approach

Nonpoint sources of pollution and new and emerging threats facing point source facilities, such as the control of mercury, pharmaceuticals, and evolving microbiological organisms, has required re-examination of the mechanisms being used to control water pollution. These substances get into water via wastewater treatment plants, livestock operations, and leaking septic systems. Wastewater treatment systems vary in terms of their ability to remove such substances. These types of pollutants were not considered when traditional treatment controls

³ Colorado had an active nonpoint control program prior to the 1987 CWA amendments. The state also responded to the CWA requirements by developing an assessment report describing the impact of nonpoint sources on the water resources of the state and establishing a management program outlining how the state would address impacts identified in its biennial assessment reports (WQCD 2000). See chapter 2, “*Water Quality Planning and Management in Colorado*” for further background on Colorado’s nonpoint source control program.

⁴ The full title of this report is the 2010 *Integrated Water Quality Monitoring and Assessment Report* as prepared by the Water Quality Control Division and approved by the Water Quality Control Commission. The Integrated Report is also referred to as the CWA section 305(b) report, which includes the CWA section 303(d) list (or list of water quality impairments).

were designed. This means that new and more effective treatment solutions may need to be applied. Moreover, if the sources of the pollutants are diffuse, then different types of pollution prevention activities may need to be undertaken.

The legal and regulatory framework for water pollution control has primarily focused on addressing specific pollutants, pollutant sources, and/or water uses. Water quality problems, however, manifest themselves in numerous ways and at various scales. An integrated environmental approach to water quality management is required. This integrated approach is often referred to as *the watershed approach*.

EPA defines a watershed approach as “a coordinated framework for environmental management that focuses public and private efforts on the highest priority problems within hydrologically-defined geographic areas taking into consideration both ground and surface water flow” (USEPA 2010e). See the sidebar for a list of key elements that constitute *the watershed approach*.

The SWQMP is one means through which the Water Quality Control Division (WQCD) is implementing a watershed-based approach to water quality management. For example, the SWQMP integrates water quality assessment data on a sub-basin and basin scale (i.e., from an administrative to a geographic scale). It also summarizes stressors and sources to the extent this information is known. The SWQMP is intended in part as a planning tool to enable the Division to strategically address priority water quality issues throughout the state.

4.4 Systems, Stressors, Sources, and Strategies

As discussed in chapter 1, “*Introduction and Background*,” the SWQMP continues to shift the state’s water quality planning and management activities toward an adaptive management or watershed-based approach. In such an approach, it is critical to identify the *systems* (watersheds at various scales) to be protected, the *stressors* to the biological, chemical, and physical integrity of the watersheds at issue, and the *sources* of such stressors. From this information, *strategies* appropriate to the scale of the problems can better be identified and implemented. Ideally, the effectiveness of strategies will be measured so that the adaptive management process can be re-tuned as needed.

The SWQMP will facilitate prioritization of the WQCD workload and budget expenditures toward problems having the greatest scope, magnitude, or impact by virtue of organizing information on systems, stressors, and sources at various watershed scales. Regional and local entities can also use elements of the SWQMP in their planning efforts.

A Watershed Approach ...

- ◆ **Is hydrologically defined**
 - ❖ geographically focused
 - ❖ includes all stressors (air and water)
- ◆ **Involves all stakeholders**
 - ❖ includes public (federal, state, local) and private sector
 - ❖ community based
 - ❖ includes a coordinating framework
- ◆ **Strategically addresses priority water resource goals** (e.g. water quality, habitat)
 - ❖ integrates multiple programs (regulatory and voluntary)
 - ❖ based on sound science
 - ❖ aided by strategic watershed plans
 - ❖ uses adaptive management.

Source: USEPA 2010e.

Systems. The ultimate objective of watershed protection activities is the protection of public health and the environment. In CWA terms, this equates to classified uses and water quality standards. The aim is to protect people from short- and long-term health effects from exposure to pollutants either through ingestion or through secondary contact, such as through recreation. The bottom line measures of environmental health tend to be (1) impacts to ecological communities or assemblages of communities that share common processes; (2) features such as soils and geology; (3) gradients such as precipitation and climate; (4) species and types impacted (e.g., imperiled, endangered, focal, keystone, wideranging, groupings that share natural processes or have similar requirements); and (5) individuals. Natural systems and related processes have overarching implications on both human and environmental health (Low 1999).

While watersheds of various sizes are the units or overall systems that are generally discussed in terms of protection, it is really the underlying factors relating to human or environmental health taking place within that watershed that are the true targets. Effective watershed protection is about selecting the right targets. When picking ecological targets, for example, care must be taken to account for factors such as size, condition and landscape context (Low 1999). EPA and other organizations have developed tools to enable watershed groups and others in undertaking these efforts, such as EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA 2008) and the *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG 1998).

Stressors. It is important to independently evaluate specific stressors on the system target separate from the sources of that stressor. If only threats in a broad sense are evaluated, certain critical nuances can be missed. For example, a new housing development might be considered a threat to a system. Therefore, stopping the housing development from occurring may be the preferred approach. If, however, stressors were evaluated separately from sources, the stress may in fact be increased sediment loadings, and the source is inadequately installed or maintained silt fencing on construction properties. This assessment could lead to an entirely different set of strategies being devised (Weeks 1997; Low 1999).

Watersheds typically experience more than one stress at any given time. It is therefore important to evaluate stressors in terms of the severity and scope both occurring now and for some period into the future. Most guidance sources recommend looking at human induced stressors rather than natural disturbances, since environmental systems are always subject to natural disturbances. Decisions also need to be made regarding how to address historical stressors. If these stressors were already considered while assessing the initial integrity of the system target, they should not be double-counted in a stressor evaluation. Stressors should be developed and ranked in some fashion for each target (Low 1999).

Sources. Once stressors are identified, sources can be determined. There are often multiple sources for any given stressor. Factors to consider when assessing sources are severity, scope, magnitude, and irreversibility. If the ultimate source is something like population growth or climate change, the most proximate sources should be assessed (Low 1999). After all sources are identified for a given stressor, it is important to rank them using some schema to identify the primary source(s).

Exhibit 4-1 provides examples of stressors and sources often identified in watershed protection efforts. It should be noted that the identification of sources is not meant to blame anyone economic land or water use activity listed. Most human activities can be undertaken in a compatible or incompatible manner. Exhibit 4-1 also includes a list of EPA’s categories of nonpoint source pollution.

Exhibit 4-1. Example Stressors and Sources

Stressors	Sources	EPA Categories of Nonpoint Source Pollution
<p>Human-induced Stressors</p> <ul style="list-style-type: none"> • Natural fire regime alteration • Composition/structure alteration • Excessive herbivory • Extraordinary competition for resources • Groundwater depletion • Habitat destruction or conversion • Habitat fragmentation • Habitat disturbance • Loss of genetic diversity • Modification of water levels; changes in natural flow patterns • Nutrient loading • Pathogens/diseases • Resource depletion • Salinity alteration • Sedimentation • Thermal alteration • Toxins/contaminants <p>Source: Low 1999.</p> <p>Natural Stressors</p> <ul style="list-style-type: none"> • Hurricanes • Tornados • Fire • Lightning • Volcanic eruptions • Earthquakes • Tsunamis • Insects and disease • Landslides • Avalanches 	<p>Agriculture and Forestry</p> <ul style="list-style-type: none"> • Incompatible crop production practices • Incompatible livestock production practices • Incompatible grazing practices • Incompatible forestry practices <p>Land Development</p> <ul style="list-style-type: none"> • Incompatible primary home development • Incompatible second home/resort development • Incompatible development of roads or utilities • Conversion of agriculture or silviculture <p>Water Management</p> <ul style="list-style-type: none"> • Dam construction • Ditches, dikes, drainage or diversion systems construction • Rivers or streams channelization • Incompatible operation of dams or reservoirs • Incompatible operation of drainage or diversion systems • Excessive groundwater withdrawal • Shoreline stabilization <p>Point Source Pollution</p> <ul style="list-style-type: none"> • Industrial discharge • Livestock feedlot • Incompatible wastewater treatment • Landfill construction or operation 	<p>EPA Categories of Nonpoint Source Pollution</p> <ul style="list-style-type: none"> • Abandoned Mine Drainage • Agriculture • Forestry • Hydromodification and Habitat Alteration • Marinas and Boating • Roads, Highways and Bridges • Urban Areas • Wetland and Riparian Management <p>Recreation</p> <ul style="list-style-type: none"> • Incompatible recreational use • Recreational vehicles <p>Land/Resource Management</p> <ul style="list-style-type: none"> • Incompatible commercial/industrial development • Fire suppression • Incompatible management of/for certain species <p>Biological</p> <ul style="list-style-type: none"> • Parasites/pathogens • Invasive/alien species <p>Source: Low 1999.</p>
<p>*These natural phenomena are likely to occur at greater frequencies due to global climate change. Sources: FISRWG 1998; Salafsky et al. 2008.</p>		

Strategies. Once stressors and sources have been evaluated and ranked, strategies can be developed. Strategies are the actions that might be taken to address the problems identified for a given waterbody. Strategies typically consist of a mix of linked activities (see inset below). They should be developed for each of the highly ranked stressors and sources.

Strategies can be regulatory or voluntary. Generally, both types of strategies are at play in most watersheds. Federal and state water quality managers are involved in both activities. They are involved in implementing and overseeing regulatory actions, and they are involved in providing incentives to encourage voluntary actions on the part of landowners, specific groups, and the general public. Additionally, they may provide resources to increase capacity for voluntary actions at the local level. Local watershed or other groups might also be involved in employing

regulatory and voluntary strategies. They may serve as the impetus for new laws and regulations, or they might help implement regulatory requirements in a specific location. Moreover, they may champion the benefits of specific voluntary programs to landowners and, through that, bring about voluntary actions.

There are a number of resources available to assist planners with strategy development, including establishing goals and objectives, such as EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA 2005a) and Colorado's *Watershed Cookbook: Recipe for a Watershed Plan* (WQCD 2010a). Clear planning enables strategic actions to be identified that are linked to objectives and that are focused, feasible, and measurable.

Factors to consider when determining strategies include their direct and indirect benefits, such as the likely *scope and scale* of strategy implementation, *contribution* or degree to which the action contributes to achievement of a stated objective, *duration of the outcome* (short versus enduring), ability of strategy to *leverage* other actions, parties, or resources, and *feasibility* (personal or partner capacity to implement, costs, ability to motivate key stakeholders such as landowners to take actions, ease of implementation, and time) (Low 1999).



Watershed planning is a mechanism used to assess and evaluate systems, stressors, sources, strategies and measures for success. Exhibit 4-2 summarizes some of the key features of watershed planning.

Exhibit 4-2. Watershed Planning and Funding Sources for Watershed Protection

Planning

Watershed-based planning is generally undertaken by a group of local volunteer organizations. The missions of the watershed groups vary; some might form to address a single water quality issue, while others might take a broader view and concentrate on improving the health of the watershed as a whole. In any event, the watershed drainage is a logical planning boundary in which the impacts of human activities, point source and nonpoint source discharges, changes in vegetation, biota, precipitation, and weather patterns converge to exert a cumulative or synergistic impact on the waterbody. EPA has suggested that the watershed planning process should entail the following steps:

- ◆ Build partnerships.
- ◆ Characterize the watersheds.
- ◆ Establish goals and identify solutions.
- ◆ Design an implementation plan.
- ◆ Implement the plan.
- ◆ Measure progress and make adjustments, if necessary.
- ◆ Improve the plan.

A successful watershed plan likely will require group members or consultants with technical expertise in hydrology, geomorphology, water quality and hydraulic modeling, aquatic biology, bioassessment and water quality monitoring, BMP development and sizing, and wastewater treatment. For more information, see EPA's Watershed Planning website at <http://iaspub.epa.gov/watershedplan/planning> or Colorado specific information at Nonpoint Source Colorado at <http://npscolorado.com/>.

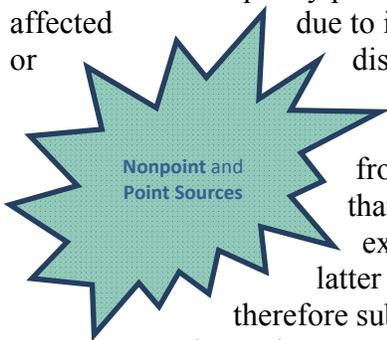
Funding

EPA maintains a searchable database called, *Catalog of Federal Funding Sources for Watershed Protection*, which provides information on grant and cost-sharing opportunities for watershed protection activities. The catalog can be accessed at <http://cfpub.epa.gov/fedfund/>. The site has further links to other sources of financial resources.

Sections 4.5 through 4.10 present potential strategies for addressing a range of known pollutant sources.

4.5 Agricultural Strategies⁵

Incompatible land use practices in terms of crop production, livestock operations, and grazing can lead to water quality problems. Ground and surface water levels or flows can be negatively affected due to irrigation methods. Habitat can be destroyed, converted, fragmented or disturbed by some crop and livestock operations. Finally, excessive nutrients (nitrogen and phosphorus), pathogens (bacteria), salts, sediment, and pesticides can make their way into surface waters from certain crop and livestock operations. Agricultural operations that impact water quality are generally defined as nonpoint sources, except for concentrated animal feeding operations (CAFOs). These latter operations meet the CWA definition of a point source and are therefore subject to National Pollutant Discharge Elimination System (NPDES) permit requirements. Although agriculture is a potential source of water quality impairments, it also presents opportunities for energy production and carbon sequestration—key elements in the *Colorado Climate Action Plan: A Strategy to Address Global Warming (Colorado Climate Action Plan)* (Ritter 2007).



⁵ The agricultural strategies described in this section were largely summarized from EPA's Nonpoint Source website. For more information, see <http://www.epa.gov/owow/NPS/MMGI/agricult.html>. There are many other useful sources of agricultural BMPs, such as the U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS) (<http://www.nrcs.usda.gov>), state agricultural agencies such as Colorado's Department of Agriculture (<http://www.colorado.gov/ag>), land grant universities, soil conservation services, cooperative extension agencies, and producer organizations.

4.5.1 Erosion and Sediment Control

Erosion and sediment discharges from cropland can impair benthic aquatic communities and transport other pollutants that are bound to the sediment, including phosphorus and pesticides. Sediment discharges can be controlled through erosion control or structural BMPs to remove sediment prior to discharge to surface waters. Erosion control practices are more effective than sediment removal, and they have the added benefit of retaining valuable topsoil in the field.

The U.S. Department of Agriculture (USDA), Soil and Conservation Service, *Field Technical Service Guide* describes a Conservation Management System (CMS) to minimize the discharge of sediment from agricultural fields to surface waters. The system includes measures such as cover crops, perennial crops, conservation tillage, contour farming, filter strips, grassed waterways and riparian buffers, and sedimentation basins (USEPA 2010d). EPA recommends that sedimentation basins be designed for at least a 10-year, 24-hour storm frequency. For more information, see EPA's Nonpoint Source website at <http://www.epa.gov/owow/NPS/MMGI/Chapter2/ch2-2f.html>.

Agriculture—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Depletion or alteration of groundwater or surface water flows
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Nutrient loading
- ◆ Pathogens and disease
- ◆ Salts
- ◆ Sedimentation
- ◆ Thermal alteration
- ◆ Pesticides
- ◆ Fish Kills

Potential Sources

- ◆ Incompatible land use practices in terms of crop production practices, livestock production, and grazing
- ◆ Incompatible water management (incompatible construction or operation of ditches, dikes, drainage or diversion systems; channelization of streams and rivers; and excessive groundwater withdrawal)

Potential Strategies

- ◆ Erosion and sediment control
- ◆ Irrigation water management
- ◆ Agricultural drainage
- ◆ Nutrient management on croplands
- ◆ Pesticide management
- ◆ Livestock operations
- ◆ Carbon sequestration

4.5.2 Irrigation Water Management

Irrigation is a consumptive use of water that can concentrate pollutants in soil, groundwater, and return flows. Depending on the local soil conditions and the type of irrigation system employed, return flows might transport the following types of pollutants to surface waters and groundwaters:

- ◆ Sediment and particulate organic solids
- ◆ Pollutants adsorbed to particulates, including phosphorus, metals, and pesticides
- ◆ Water-soluble salts, including nitrate and selenium
- ◆ Bacteria.

Return water can be treated to reduce sediment and other pollutants prior to discharge. Control measures include the following:

Researchers in Minnesota are experimenting with in-ground "wood chip bioreactors" to reduce nitrate discharges from cropland. In one experimental installation, the bioreactor consists of a trench approximately 6 feet deep, 30 inches wide, and 155 feet long, filled with 75 cubic yards of wood chips. A capacity control structure regulates how fast the water flows through the bioreactor. The drainage water flows through the bioreactor before discharge off-site. Anaerobic soil microbes feed on the carbon in the wood chips and convert nitrate to nitrogen gas. Preliminary experiments have shown nitrogen reductions of up to 60 percent (Morrison 2008).

- ◆ Irrigation scheduling
- ◆ Efficient application of irrigation water
- ◆ Efficient transport of irrigation water
- ◆ Use of return flow water
- ◆ Treatment of return flow water prior to discharge to surface waterbodies.

A well-managed irrigation system minimizes water consumption and loss, the discharge of sediment, and the discharge of water-soluble pollutants, and it reduces deep percolation into underlying aquifers. Changes in the water table can cause leaching of soluble salts (e.g., selenium) from geologic formations. Therefore, the impacts of irrigation and drainage on the water table should be addressed in the overall irrigation management system.

The design of an efficient irrigation schedule must take into account the needs of the crops at various stages in growth, weather conditions, and soil properties. A means to effectively adjust water stream size, application rate, or irrigation timing is a necessary component of an efficient irrigation system.

Transport of irrigation water through unlined ditches and canals can result in water loss through seepage. Lining these conveyances or replacing them with piping can conserve water supplies and reduce leaching of soluble salts such as selenium. Impacts on groundwater recharge and downstream water rights are other factors that must be considered when employing this strategy.

Treatment of return flows prior to discharge may include settling basins to remove sediment and the pollutants most often bound to sediment (phosphorus and some pesticides). However, the settling basin is not an effective treatment for water-soluble pollutants, which include nitrate, other salts, and some pesticides.

Wetlands can be used to remove nitrate from irrigation water or stormwater runoff through denitrification; however, constructed wetlands can sometimes take land out of agricultural use. Whether a constructed wetland or an existing native wetland is utilized, a wetland is likely to host aquatic life, birds, and other wildlife. Therefore, before selecting a wetland as a treatment option for reducing nitrogen, the farm manager should analyze the return water for other pollutants (such as pesticides and selenium) that might be harmful to the wetland biota.

4.5.3 Agricultural Drainage Management

Colorado State University is working with the farmers in the Lower Arkansas Valley to address drainage issues and the water quality of the return flows. In 2005 researchers identified and refurbished old drainage systems that had been abandoned and not maintained. A new drainage system was designed and installed using the Agricultural Drainage Planning Program (ADPP), a computer model developed for the U.S. Bureau of Reclamation by the Integrated Decision Support Group at Colorado State University (CSU N.d.).

Irrigation combined with poor drainage can raise the groundwater table, saturating soils or underlying geologic formations containing selenium and other salts. These salts may leach into the groundwater and be transported with irrigation return flows. Improved drainage can be used to control the groundwater elevation and reduce discharges of salts.

4.5.4 Nutrient Management on Cropland

Nutrient management programs are designed to limit the amount of nitrogen and phosphorus applied to cropland. The amount of nutrients applied depends on the soil chemistry and the crop type. When manure is applied on cropland, the loading should be calculated based on the lower requirement for phosphorus and then supplemented with nitrogen fertilizer as needed. Buffer grass strips between fields and drainages can be used to reduce nutrient transport to surface waters. Even with the best nutrient management systems, however, treatment measures will likely be necessary to control surface and groundwater discharges of nitrogen and phosphorus from cropland.

The Colorado Department of Agriculture (CDA) has developed nutrient management programs designed to minimize the potential for contamination of drinking water wells. CDA posts fact sheets on its website describing BMPs to protect water wells from sources of nitrate contamination, and it provides a soils map showing areas of varying permeability and risk of groundwater contamination. Nitrate-nitrogen contamination has significantly affected groundwater quality in several groundwater basins in Colorado (WQCD 2005).

4.5.5 Pesticide Management

4.5.5.1 Nonpoint Source Pesticide Management Strategies

CDA's Division of Plant Industry is responsible for the review and approval of pesticide registrations in Colorado. CDA also regulates pesticide sales and licenses applicators of restricted-use pesticides. CDA has initial responsibility for addressing potential groundwater contamination from agricultural chemicals (pesticides and commercial fertilizers). CDA posts fact sheets on its website describing BMPs to protect water wells from pesticide contamination. Monitoring has indicated the presence of pesticides in a few wells in Colorado, but very few wells have pesticide concentrations that exceed the maximum contaminant levels established under the federal Safe Drinking Water Act (WQCD 2005).

Pesticides can enter surface waters through direct application, as in the case of aquatic-use pesticides, stormwater runoff, agricultural return water, and runoff and drains from residential lawns and gardens. Management measures for reducing pesticide contaminants in groundwater and surface water include the following (CDPR and SWRCB 1997):

- ◆ Use integrated pest management strategies that employ means for minimizing pest infestations (e.g., crop rotation, natural predators to control pests).
- ◆ Minimize water, soil, and sediment loss from treated sites.
- ◆ Prevent transport of runoff from treated areas to surface waters and wetlands and sites that might serve as pathways for groundwater contamination through the use of buffer strips.
- ◆ Divert runoff from treated areas away from production water wellheads, dry wells, or infiltration basins.
- ◆ Select pesticides that are not known or suspected to be surface water or groundwater contaminants.

- ◆ Use pesticides that are most selective for the target species.
- ◆ Read the pesticide container label carefully and apply in accordance with the label instructions.
- ◆ Use the lowest application rate and frequency proven effective.
- ◆ Recalibrate spray equipment frequently to ensure the accuracy of the application rate.
- ◆ Match the pesticide application rate to the most susceptible growth stage of the target pest.
- ◆ Avoid long-term, repeated use of a single pesticide to avoid pest resistance.
- ◆ Incorporate weather conditions and irrigation schedule into the planning of pesticide application. Allow at least 12 hours between application and predicted rain events.
- ◆ Minimize drift; apply only when wind speed is low.
- ◆ Use low delivery pressure and nozzles that do not create small particulates that are more prone to drift.
- ◆ Mix, load, and store pesticides at least 100 feet away from any water sources, wellheads, and sinkholes.
- ◆ Store pesticides in a clean, dry, and secure site.
- ◆ Use enclosed mixing systems to triple-rinse pesticide containers, and safely apply the rinsate to the target field.

4.5.5.2 Point Source Pesticide Management Strategies

Effective April 9, 2011, those who apply certain pesticides to waters of the United States will be required to obtain coverage under a NPDES permit. EPA is the permitting authority for federal facilities and Indian Country lands in Colorado; WQCD is the permitting authority for other facilities in the state that are not subject to EPA's authority.

The NPDES permit will apply to vector control boards and other organizations that apply pesticides directly to water to control pests, such as mosquitoes, and to dischargers that apply pesticides to control weeds near ditches or rivers. The permit will not apply to discharges from agricultural tiles or drains because they are specifically exempted from permitting requirements under the CWA. EPA had issued a final rule that would *not* have required an applicator of aquatic-use pesticides to obtain coverage under an NPDES permit, provided the applicator complied with the pesticide registration label requirements. On January 7, 2009, however, the Sixth Circuit Court of Appeals held that EPA's final rule regarding pesticide applications was not a reasonable interpretation of the CWA and vacated the rule. The court granted a 2-year stay of the mandate to allow EPA and the states time to develop a general permit for the application of pesticides (Scott 2010).

4.5.6 Livestock Operations Management

4.5.6.1 Nonpoint Source Compatible Livestock Operational Strategies

There are approximately 13,300 cattle feeding operations in Colorado, most of which have fewer than 100 head of cattle. Approximately 980 operations are considered animal feeding operations (AFOs) or CAFOs. Feeding operations account for approximately 40% of the cattle raised in the state (WQCD 2005). CAFOs are point sources as defined under section 502(14) of the CWA. To be considered a CAFO, a facility must first be defined as an AFO. The federal definition of an AFO is a "...lot or facility (other than an aquatic animal production facility) where the following conditions are met: animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." (USEPA 2011a). A CAFO is determined based on the number of animals at the facility (see CAFO point source discussion under section 4.5.6.2 below). While CAFOs are point sources, AFOs are not.

Manure from AFOs and CAFOs can be a significant source of nutrients, *Escherichia coli*, antibiotics, hormones, salts, and trace metals. AFOs are eligible to receive nonpoint source grant funding (i.e., CWA section 319 grant funding) to develop and implement a comprehensive nutrient management plan. Facilities that accept manure from off-site CAFOs and that are not subject to point source discharge permit requirements are also eligible for nonpoint source funding. The nonpoint source activities that are eligible for funding under a CWA section 319 grant are defined in the state's Nonpoint Source Management Plan (WQCD 2000, 2005).

Livestock grazing can occur on large expanses of open rangeland consisting of primarily native, unmanaged vegetation or on fenced pastures, which are typically smaller and consist of cultivated grass. Allowing livestock access to creeks can cause erosion and destabilize bank structures. Animal wastes (bacteria) also get into water in this manner. In rangelands, water can be pumped to upland watering tanks or ponds in an attempt to keep livestock out of creek beds. Fencing is another means to keep animals out of water. In areas of heavy use, foundations and grade stabilization can be used to protect a creek's bank structure.

Pastures should be fenced to exclude cattle from the riparian zone. Preservation or restoration of riparian corridor buffers provides added protection to the waterbody and filter out nutrients and pathogens from manure. Designing the pasture to allow for rotational grazing and to prevent overgrazing also will reduce pollutant runoff. Local Soil and Water Conservation Districts are a source for more detailed information on pasture management. This information has been summarized from EPA's Nonpoint Source website. For more detailed information, see <http://www.epa.gov/agriculture/anprgidx.html>.

Many of the strategies applicable to nonpoint sources are also applicable to point sources but at different scales.

4.5.6.2 Point Source Compatible Livestock Operational Strategies

The USDA estimates that, nationally, CAFOs generate about 500 million tons of manure per year—three times the annual volume of human sanitary waste (150 million tons) (USEPA

2009b). Colorado ranks fourth in the country in the number of cattle “on feed.” These cattle are raised on small AFOs or CAFOs. In Colorado, CAFOs are defined by the number and type of animals confined, or a facility is regulated as a CAFO if either of the following conditions is met (WQCD 2005):

- ◆ Pollutants are discharged to waters of the state through a man-made drainage system, or
- ◆ Pollutants are discharged directly into surface waters of the state that originate outside and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operations.

BMPs for managing manure include composting for soil amendment and biodigesters with biogas recovery. Composting manure at sustained temperatures of 140 degrees Fahrenheit (°F) to 160 °F substantially reduces pathogens. Composting facilities, however, can be a source of nitrate contamination in groundwater unless properly designed and operated. Composting operations should be performed on an impervious base and be covered to prevent rain and run-on to control moisture content and to prevent the formation of leachate, which can then transport nitrate to shallow groundwater or surface water.

Manure can also be managed through anaerobic digestion, which can be combined with a biogas recovery system. The *Colorado Climate Action Plan* (Ritter 2007) specifically identifies biogas recovery technologies as a strategy for reducing greenhouse gases. Farmers installing biogas facilities might be eligible for future carbon emission offset credits under the Western Regional Agricultural Offset Program. Currently, approximately 150 livestock biogas systems operate in the United States, reducing methane emissions by almost 1 million metric tons of carbon dioxide equivalency per year. The project provides enough energy to power the equivalent of 20,000 average American homes (USDA and USEPA 2010). The AgSTAR website at <http://www.epa.gov/agstar/tools/index.html> provides additional up-to-date information on the program, including the following Web-based tools:

- ◆ The *AgSTAR Handbook*, which provides guidance on developing biogas technology on commercial farms
- ◆ The *Market Opportunities Report*, which assesses market potential for biogas energy projects at swine and dairy farms
- ◆ Funding information, including low-interest loans, grants, and tax incentives
- ◆ Industry directory of consultants, project developers, energy services, manufacturers, distributors, and commodity organizations
- ◆ *USDA-NRCS Biogas Interim Standards*
- ◆ Protocol for quantifying and reporting the performance of anaerobic digestion systems for livestock manures
- ◆ Digester performance evaluations characterizing the environmental and financial benefits of anaerobic digesters.

4.5.7 Carbon Sequestration

Agriculture in Colorado is a source of water quality impairment, but it is also a key element in the *Colorado Climate Action Plan* because it provides significant potential for carbon sequestration. The Action Plan sets goals and establishes programs to promote agricultural practices that sequester carbon, reduce greenhouse gases, or both. The Action Plan establishes the Western Regional Agricultural Offset Program and requires the CDA and Colorado Department of Public Health and Environment (CDPHE) to develop a market mechanism for carbon trading for farmers. Several strategies designed to sequester carbon might also have water quality benefits. They include converting row crops to perennial crops and establishing conservation easements and buffer strips. For more detailed information, see <http://www.epa.gov/sequestration/>.

4.6 Forestry Strategies



Colorado's forests include national forests and state- and privately-owned forested lands. The USDA Forest Service manages the national forests and grasslands. The Colorado State Forest Service, managed at Colorado State University, manages state forests and provides guidance on managing privately-owned forests in the state.

4.6.1 Road Construction Management

EPA has identified roads as the largest source of nonpoint source pollutants from forested lands, contributing approximately 90% of the sediment load to the nation's surface waters in these areas. Roads that are constructed near riparian areas or that include stream crossings can be particularly harmful. In addition to pollutant loading, road culverts can block fish passage, and roadbeds and related structures can cause changes in streambed morphology. Harvesting of trees in the riparian corridor can destabilize stream banks, and the loss of canopy shading can cause an increase in water temperature. For more detailed information on forestry BMPs, see <http://water.epa.gov/polwaste/nps/bestnpsdocs.cfm#forestry>.

In 2001 the U.S. Forest Service promulgated the Roadless Rule that is designed to restrict road construction in undeveloped parcels of land generally greater than 5,000 acres in size or adjacent to congressionally designated wilderness areas. The federal rule has been subjected to litigation ever since its promulgation. In 2004 the Roadless Rule was repealed and a state petitioning process was instituted instead. A state Task Force put together by the Governor of Colorado developed a petition and it was submitted to the U.S. Forest Service in 2006 even though federal courts had recently reinstated the Roadless Rule. In 2007, the Governor submitted the Task Force's petition as an "insurance policy" in case the federal rule is again repealed (CFL

Forestry—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Natural fire regime alteration
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Nutrient loading
- ◆ Sedimentation
- ◆ Chemicals
- ◆ Thermal alteration

Potential Sources

- ◆ Incompatible forestry practices
- ◆ Fire suppression
- ◆ Recreational vehicles
- ◆ Incompatible recreational uses
- ◆ Biological (invasive/alien species)

Potential Strategies

- ◆ Preharvest planning
- ◆ Streamside and wetland area management
- ◆ Road construction management
- ◆ Timber harvesting
- ◆ Revegetation
- ◆ Chemical Management

2011). The Colorado petition would provide management direction for approximately 4 million roadless acres out of the 14.5 million acres of National Forest in Colorado. For more information, see the USDA Forest Service Rocky Mountain Research Center Roadless Rule website.⁶

4.6.2 Bark Beetle Infestation Management

On August 31, 2007, the U.S. Forest Service announced its proposed Bark Beetle Mitigation Plan. The bark beetle infestation was first recognized during the drought year of 1996/1997. By 2007, approximately 755,000 acres of lodgepole pine were infested in Colorado and southeastern Wyoming. In January 2010, the U.S. Forest Service estimated that more than 3.6 million acres (2.9 million acres in Colorado and 700,000 acres in southern Wyoming) were infested. Today, the U.S. Forest Service works cooperatively with the Colorado State Forest Service and the Northern Front Range Mountain Pine Beetle Working Group, a consortium of local government agencies, to identify and fund projects to address the bark beetle infestation. These projects include removing dead trees that pose a safety or fire risk, or threaten to damage infrastructure; salvaging dead trees to reduce fuel loading; treating infected trees; road construction or abandonment; and other projects. For more information, see the USDA Forest Service Bark Beetle Management website.⁷

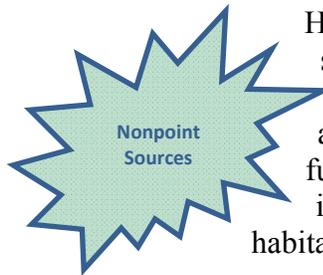
The bark beetle infestation is expected to destroy 85% to 90% of the mature lodgepole ecosystems in Colorado and Wyoming within the next 4 to 5 years (USFS 2009). The general belief has been that wildfires are expected to increase with the large amount of available fuel, although more recent research suggests this may not be the case (USFS 2002; Simard et al. 2009). Burned areas are susceptible to high erosion, mudslides, and debris flows, especially in mountainous areas. The loss of upland canopy cover might cause the snowpack to melt more quickly (Ciesla 2009). The loss of trees might increase the peak flow and flow duration rates, causing flooding and undercutting of the creek beds. The U.S. Forest Service's hydrologic models suggest that initially the water yield might increase by 30% in some watersheds. As the forest regrows, water yields are expected to return to the pre-existing conditions, but that is likely to take 50–60 years (USFS 2008). Factors related to climate change or other factors might affect the actual recovery and changes in hydrology. The U.S. Forest Service's Rocky Mountain Research Station plans to evaluate the following potential impacts of the infestation and the mitigation measures (USFS 2009):

- ◆ Impacts of the bark beetle (related to tree mortality) on the supply of clean water and processes that regulate its delivery.
- ◆ The influence of salvage operations on nutrient, carbon, sediment, and large wood retention within riparian buffers.
- ◆ Impacts of mechanical fuel reduction treatments and post-harvest site preparation impacts on seedling establishment and growth, plant nutrient and moisture relations, and biogeochemical and hydrologic processes.
- ◆ Impacts of forest road construction and retirement on hill slope hydrology and nutrient and sediment fluxes.

⁶ This document can most easily be found by searching for “forest roadless rule” at www.colorado.gov.

⁷ This document can most be found by searching for “Forest Service Bark Beetle Management” at www.fs.fed.us.

4.7 Hydromodification Strategies



Hydromodification is one of the leading sources of impairment in streams, lakes, estuaries, aquifers, and other waterbodies in the United States (USEPA 2007). Dams, dikes, diversion systems and channels alter the physical structure of a waterbody and, in turn, its natural function. The waterbody can be impacted by changed flow conditions, increased sedimentation, temperature differentials, decreased aquatic habitat and populations or communities, and decreased chemical integrity.

The stressors and sources that result in hydromodification are generally nonpoint. Hydromodification issues tend to be addressed under the *water quantity* (water use) versus *quality* arena. Water quantity issues tend to be more contentious than quality issues. Water rights are protected under Colorado's constitution and several state statutes (CFWE 2003). WQCD may not take actions under its Nonpoint Source Management Program that would supersede, abrogate, impair, or cause material injury to water rights (WQCD 2005). In spite of the natural tensions or different management entities between the water quality and quantity arenas, public and private entities involved in watershed protection have grown to appreciate that the two worlds are inexplicably linked. Numerous examples exist where the two arenas have joined forces to address hydromodification problems.

4.7.1 Minimizing Channelization of Rivers and Streams

In numerous locations throughout the state, rivers and streams have been channelized for a variety of purposes. In most instances the channelization occurs from direct human impacts such as straightening and armoring for perceived flood control. In other instances, such as the example below, the channelization was not intentional but rather the result of upstream activities. Lately, stakeholders throughout Colorado have been working to minimize or eliminate channelization and restore the natural floodplain of rivers and streams.

An example of an effort to minimize channeling of a river is the Colorado Water Conservation Board (CWCB) efforts to lead a diverse group of stakeholders and state agencies in the successful restoration of the Lower Rio Blanco located in Archuleta County in Southwest Colorado. A basin summary prepared in 1990 by the U.S. Forest Service found that diversion and land use practices created a wide and shallow stream with very little pooling or cover habitat. Fish habitat in the Lower Rio Blanco was poor, sediment loads were high due to flow

Hydromodification—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Composition/structure alteration
- ◆ Flow and water level alteration
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Nutrient loading
- ◆ Toxics (metals), pesticides, hydrocarbons and other chemicals
- ◆ Sedimentation

Potential Sources

- ◆ Dam construction and incompatible operation
- ◆ Construction and incompatible operation of ditches, dikes, drainage or diversion systems
- ◆ Channelization of rivers and streams
- ◆ Excessive groundwater withdrawal
- ◆ Destabilization of shorelines

Potential Strategies

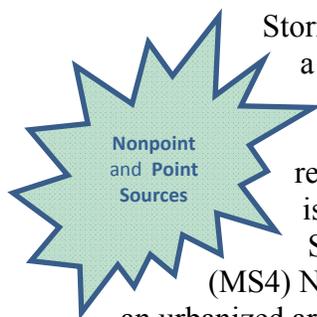
- ◆ Dam removal or modifications in operation
- ◆ Deconstruction of other drainage and diversion systems or changes to their operation
- ◆ Vegetation
- ◆ Planning and regulatory controls

changes and stream bank erosion, sediment supply was greater than stream transport capacity and water temperatures were high. Project highlights included:

- ◆ This was the first project implemented by the Colorado Nonpoint Source Program addressing hydrologic modifications. Due to legislative mandated flow regime (decreased original flow by 70%), providing sufficient flow for aquatic life and habitat support and water quality was not possible, so instead, this project aimed to reconfigure the channel to adjust to the new flow regime.
- ◆ This reach of the river was originally listed as impaired for sediments and aquatic life; due to the nonpoint source (NPS) project, no TMDL was necessary and the impairments were addressed and significantly resolved.
- ◆ This reach of the river flows through a mix of private and public lands; there was 100% collaboration among the different parties implementing the project.
- ◆ Work on this reach of the river is continuing, through regular monitoring, remedial activities, and on-going collaboration.

At completion, the project restored approximately 3.25 miles of river by installing rock vortex weirs, bank protection, stream meanders and grade control. Some property owners conducted reforestation and the floodplain has naturally restored itself with native willow growth due to improved rainfall. Fishery habitat has been improved through the enhancement of riffles and pools. One of the project goals was to improve the water quality impacts of sedimentation, temperature, and low dissolved oxygen levels. Recent monitoring results by the Colorado Department of Natural Resources, Division of Water Resources indicated a marked improvement in all these areas (WQCD N.d.).

4.8 Land Development/Stormwater Control Strategies



Stormwater can be categorized as a nonpoint source in smaller, more rural, communities.

In urban areas, stormwater is regulated as a point source and is subject to a Municipal Separate Storm Sewer System (MS4) NPDES permit. EPA defines an urbanized area as follows:

An urbanized area is a land area comprising one or more places—central place(s)—and

Land Development/Stormwater—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Composition/structure alteration
- ◆ Flow and water level alteration
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Nutrient loading
- ◆ Contaminants
- ◆ Sedimentation
- ◆ Thermal alteration

Potential Sources¹

- ◆ Construction sites
- ◆ Homes
- ◆ Municipalities
- ◆ Industries

Potential Strategies

- ◆ Green roofs
- ◆ Minimizing impervious cover
- ◆ Green streets
- ◆ Rain gardens
- ◆ Restoring or adding riparian corridors/buffers
- ◆ BMPs for mountain driveways
- ◆ Erosion control
- ◆ Revegetation

¹In urban areas, stormwater is regulated as a point source and is subject to a Municipal Separate Storm Sewer System (MS4) NPDES permit. Stormwater is generally considered to be nonpoint when occurring in smaller and more rural communities.

the adjacent densely settled surrounding area—urban fringe—that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile (USEPA 2005).

Some strategies to control stormwater as either a nonpoint or point source are discussed below.

4.8.1 Unregulated Stormwater (Nonpoint) Control

Unregulated stormwater runoff can affect water quality as well as hydrology. Pollutants often associated with stormwater runoff include copper and zinc from automotive brakes and tires; polyaromatic hydrocarbons from petroleum products; and nitrogen, phosphorus, and pesticides from lawns and landscaped areas. An increase in impervious cover (generally paved areas) is linked to an increase in peak flows, a decrease in base flows, and an increase in water temperature and sediment. Increased peak flows have been linked to bank destabilization and, over time, a widening of the stream channel. The loss of riparian canopy can contribute to increasing water temperature. Water temperature increases can also result from the decrease in groundwater contributions to the base flow during periods of low rainfall. Impervious cover and flow have been identified as surrogate pollutants in TMDLs as an indicator of multiple pollutants that are causing impairment of aquatic life beneficial uses as outlined in an EPA internal memorandum dated November 12, 2010 (Hanlon and Keehner 2010).

4.8.1.1 Low-Impact Design

Examples of low-impact design (LID) for reducing the impact of unregulated stormwater on in-stream flow include the following (USEPA 2010d):

- ◆ **Green roofs.** The green roof installed on EPA Region 8's Denver, Colorado, office building retains more than 80% of the rainfall it receives, and it has reduced the cost of the below-ground stormwater detention vault by more than 40%. The green roof reduces the building heating and cooling costs. The rooftop plantings sequester carbon dioxide (a greenhouse gas), reduce the heat island effect, and provide habitat for birds. Additional water savings can be achieved by using the air-conditioning condensate water for irrigation. Further reductions in irrigation water can be achieved by irrigating only during the night or early morning hours and using drip irrigation methods. Green roofs have a typical life span of 40–50 years, as compared to 20–30 years for conventional roofs.
- ◆ **Porous pavement.** Porous pavement consists of porous concrete or asphalt, or interconnecting locking pavers, underlain by several layers of bedding. The bedding filters out the oil and heavy metals. The filtered water infiltrates into the underlying soil and can provide subsurface irrigation for trees that line the streets.
- ◆ **Rain gardens (bioretention cells).** Rain gardens are areas of depression that are connected to streets, parking lots, or other impervious surfaces and are planted with native or drought-tolerant plants. The plants at the lowest elevations must be able to withstand occasional inundation.
- ◆ **Green streets.** Green streets are designed to drain water to rain gardens or vegetated swales.
- ◆ **Riparian buffers.** A vegetated riparian buffer helps to disconnect runoff from impervious covered areas and retain the stream channel structure and function. Forested stream

canopies provide shade and reduce water temperatures. An intact riparian buffer provides wildlife corridors. Many communities develop recreational trails along the riparian buffer.

4.8.1.2 Other Strategies for Addressing Nonpoint Sources of Stormwater Runoff

The Colorado Nonpoint Source Management Plan describes pollutants common to developed areas and construction stormwater, and BMPs appropriate for Colorado's hydrology. These include BMPs for mountain driveways and measures for controlling erosion through re-vegetation and restoration efforts in high-altitude areas. Appendix E provides additional references related to the control of stormwater runoff from suburban and urban areas.

4.8.1.3 Designing Strategies at the Site Level

The Energy Independence and Security Act of 2007 requires federal agency buildings to incorporate green infrastructure/low-impact design elements (GI/LID) and to retain the 95th percentile rain event on-site. To assist agencies in complying with the act, EPA issued a guidance manual in December 2009, entitled *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*. The manual is a useful resource for those interested in designing BMPs at the site level. It provides the methods for calculating the 95th percentile rain event and sizing GI/LID structures. The document also includes a number of case studies, including a study in Denver, Colorado. The Denver facility consisted of a 4.5-acre site with 55% impervious cover. The 95th percentile rain event was calculated to be 1.07 inches and, based on the soil type, it was determined that 0.53 inch of rain would need to be retained to meet the standard for federal facilities. This was accomplished by installing a rain garden and bioretention cells. The cost for the GI/LID approach was estimated to be 17% less than the conventional storm drain/impoundment approach (USEPA 2009c).

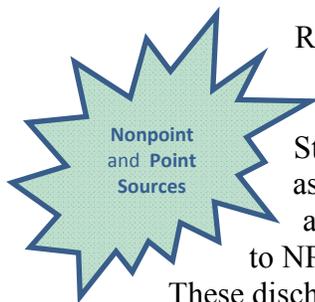
4.8.1.4 Strategies for Large-Scale Development or Re-development

Many resources describing the design of LID elements are available. A key challenge is to design a comprehensive drainage plan incorporating elements in a way that optimizes pollutant reduction and maintains or at least mimics the natural hydrology and stream morphology. In October 2009, EPA released its *System for Urban Stormwater Treatment and Analysis Integration Model* (SUSTAIN). The model is designed to allow municipalities and watershed groups to select and site BMPs in strategic locations for optimal performance. It can be used to assess BMP effectiveness and sizing considerations, and it includes cost-effectiveness curves. The model can be downloaded from <http://www.stormwaterpa.org/blog/stormwater-bmps/epa-sustain>. Another source of information for assessing BMP cost-effectiveness is the National Green Values Calculator, which can be used to compare green infrastructure performance, costs, and benefits to conventional stormwater practices. It can be accessed at <http://greenvalues.cnt.org>.

4.8.2 Permitted Stormwater Control

The discharge of polluted stormwater can significantly impact water quality and impede attainment of classified uses. The goal of the stormwater NPDES permits program is to reduce the amount of pollutants entering streams, lakes and rivers as a result of runoff from residential, commercial and industrial areas. In Colorado, stormwater discharge permits are issued by the WQCD under Regulation No. 61: *Colorado Discharge Permit System Regulations* (5 CCR 1002-61). The Division regulates stormwater pollution by issuing permits for stormwater discharges from industry and construction sites and to government entities (municipalities) that are responsible for stormwater discharges from urban areas. For additional details regarding stormwater regulations and permits, visit <http://www.cdphe.state.co.us/wq/PermitsUnit/index.html>.

4.9 Recreational Boating Strategies



Recreational boating can cause point and nonpoint sources of pollutant discharges. Stormwater discharges associated with industrial activities at marinas are subject to NPDES permitting requirements.

These discharges can include stormwater runoff from areas where boats are being cleaned, sanded, or painted or areas where engine or other mechanical repairs are being performed.

4.9.1 Nonpoint Issues and Strategies

Pathogens, nutrients, and total petroleum hydrocarbons (TPH) are pollutants often associated with nonpoint source discharges from recreational boating. Pathogens (indicator bacteria such as *Escherichia coli*) and nutrients can result from the accidental spillage from the pumpout of marine sanitation devices or illicit discharges. The waste from marine sanitary devices is more concentrated than municipal sanitary wastewater, and even limited discharges can affect water quality in marina waters. TPH discharges can result from the pumping of oily bilge water or from accidental spills during fueling. More significant discharges of fuel can occur when a vessel sinks. Passive leaching of marine coatings can be a source of copper, and zinc discharges can result from sacrificial anodes. Water quality impairments for copper in some small boat harbors have been linked to the passive leaching of marine coatings (CRWQCB 2006). Other potential sources of nonpoint source pollutants from

Recreational Boating—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Extraordinary competition for resources
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Loss of genetic diversity
- ◆ Pathogens/diseases
- ◆ Nutrients
- ◆ Other pollutants/chemicals (e.g., TPH)
- ◆ Resource depletion
- ◆ Sedimentation

Potential Sources

- ◆ Marinas
- ◆ Boat spillage
- ◆ Boat sewage discharges
- ◆ Parasites and pathogens
- ◆ Invasive/alien species

Potential Strategies

- ◆ Laws and regulations
- ◆ Permitting of point sources
- ◆ Education and outreach to marinas, boatyards, and individual boaters
- ◆ BMP guidance on boat maintenance, petroleum containment, marina operations, etc.

¹EPA's NPDES program regulates incidental discharges from vessels. The program does not regulate discharges from military or recreational vessels, however. Incidental discharges include ballast water, bilge water, water from sinks and showers, and anti-foulant paints (USEPA 2011b).

recreational boating include fish cleaning waste, bait containers, trash, and pet waste (USEPA 2001b).

The Clean Marinas Colorado Project was developed in collaboration with EPA and the WQCD's Colorado Nonpoint Source Management Program, and it is run with support from the U.S. Coast Guard Auxiliary and volunteers (Clean Marinas Colorado N.d.). The program is based on the national Clean Marina Initiative promoted by the National Oceanic and Atmospheric Administration (NOAA). Clean Marinas Colorado is a voluntary program for marinas, boatyards, and individual boaters. The program provides education and BMP guidance to reduce the pollutant discharges from recreational boating activities. Educational materials address the following activities:

- ◆ Emergencies
- ◆ Petroleum containment
- ◆ Topside boat maintenance and underwater hull cleaning
- ◆ Marina operations
- ◆ Marina debris
- ◆ Boat sewage discharges
- ◆ Liquid wastes
- ◆ Fish cleaning waste
- ◆ Hazardous materials and stormwater runoff.

To gain certification as a “Clean Marina,” a marina must first pledge to implement the Clean Marina BMPs. The Clean Marina Program Coordinator then scores the marina. If the marina attains a qualifying score it is certified as a Clean Marina. Where improvement is needed the Program Coordinator provides assistance and guidance to the marina as it attempts to complete the certification process and implement a “Clean Boating Behavior Change Campaign.” Once the marina attains a qualifying score, it is certified as a “Clean Marina” and receives a program flag, certification plaque, program stickers, and three signs to be posted around the marina.

4.9.2 Controlling Aquatic Invasive Species, Pathogens, and Parasites

Recreational activities can contribute to the spread of aquatic invasive species, fish pathogens, and parasites. As described on its website, the Colorado Division of Wildlife (CDOW) licenses boats, issues fishing licenses, and provides educational materials on measures for minimizing the risk of the spread of aquatic invasive species and parasites. These measures include monitoring to identify infested waterbodies, inspection of boats and equipment, and decontamination of boats and fishing equipment. CDOW provides the most recent information on aquatic invasive species-infested waters, requirements, and prohibitions on its website. A brief summary of aquatic invasive species and fish parasites known to be present in Colorado waterbodies is provided below.

Zebra mussels have been identified in several lakes and reservoirs in Colorado. These nonnative species disrupt the food chain as they consume copious amounts of phytoplankton that juvenile fish depend on for food. CDOW conducts a boat inspection program to help prevent the spread of aquatic invasive species. The campaign includes boater education on how to decontaminate boats between launches through the principles of “clean, drain, and dry” and through a boat

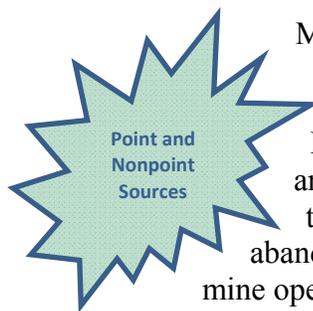
launch inspection program. Bait containers are another vector for the spread of nonnative species; they must not be emptied into any waterbody.

The rusty crayfish has been found in the Sanchez Reservoir State Wildlife Area and the Yampa River Basin. The crayfish was probably introduced by fishermen using it as bait. The rusty crayfish is an aggressive, opportunistic feeder that might outcompete native species. Further, it can carry pathogens that could be introduced to native crayfish. The Colorado Division of Wildlife issued emergency orders prohibiting anyone from removing any live crayfish from these waterbodies (Remington 2010a and 2010b).

Recreational activities can also contribute to the spread of whirling disease in trout and salmon. The disease is caused by a microscopic parasite (*Myxobolus cerebralis*). The symptoms include erratic tail-chasing behavior—thus the name “whirling disease.” The disease is most often fatal to young fish. The parasite has a two-host life cycle that includes the fish and a common bottom-dwelling tubiflex worm. Spores are released by an infected fish when it dies. The spore can survive extreme cold and drought and can remain viable for decades. The spores are ingested by the worm, which might then be eaten by trout or salmon. Alternatively, after the parasite eventually kills the host worm, the spore is released and might attach itself to the trout or salmon. The disease can be spread by infected fish or by the tiny tubiflex worm. For detailed information, see CDOW’s webpage at <http://wildlife.state.co.us/Fishing>.

Measures to prevent the spread of whirling disease include the decontamination procedures “clean, drain, and dry.” Fishing boots with felt bottoms, popular among fly fisherman, have been identified as a possible vector in the spread of whirling disease, perhaps because they are difficult to dry. The use of hot water (with temperatures of 140 °F) is generally recommended for decontaminating boats and trailers and can be used for fishing gear as well. In addition, prohibitions on transporting fish between waterbodies and disposing of fish-cleaning entrails in the waterbody are identified. (See Montana Wildlife Federation webpage at <http://www.montanawildlife.com/projectsissues/AquaticHitchhikers.htm>).

4.10 Resource Extraction, Strategies to Address Abandoned Mines



Many streams in Colorado are impaired from inactive or abandoned mines. The Colorado Division of Reclamation, Mining, and Safety (DRMS) has identified three major stressors as a result of abandoned mines. These include unsafe mine openings, contamination of streams by acidic drainage, and contamination of streams by excess sediment (DRMS 2002).

Vertical shaft entrances to old mines often cannot be seen until a person is standing next to them. The ground near the shafts can also be unstable, which could lead to a fall or cave-in. The air quality in mine openings is poor. It is oxygen limited and can contain noxious fumes or gases. Acid mine drainage contains metals (leachates of iron, copper, zinc, manganese, cadmium, lead, and arsenic) which can runoff into streams. Soils and rock piles around mines can also contain metals and runoff into water. The metals and sediment pose both public and aquatic life risks.

To learn more about the water quality problems posed by inactive abandoned mines and strategies to address these problems, consult the following DRMS manual: *Best Practices in Abandoned Mines Land Reclamation: The Remediation of Past Mining Activities* (DRMS 2002) at <http://mining.state.co.us/bmp.pdf>. In addition to

summarizing key problems, the document discusses 10 BMPs that can be used to remedy acid mine drainage and metals-laden sediment (see sidebar under “Potential Strategies”). The first six BMPs consist of hydrologic controls, while the remaining four consist of passive treatment options. Hydrologic options prevent or minimize the opportunities for water to come into contact with sulfide rocks, waste rock or tailings, which results in sulfuric acid that, in turn, leaches metals from the rock. Passive treatment options are more typically associated with drainage solutions and require minimal energy inputs and maintenance activities (DRMS 2002). The 10 BMPs are briefly summarized below based on information in the DRMS manual.

4.10.1 Hydrologic Strategies for Addressing Acid Mine Drainage

4.10.1.1 Diversion Ditches

Diversion ditches are used to reroute uncontaminated water (precipitation or snowmelt) around waste rock piles, mill tailings or draining mine openings. In this way, the runoff to the stream

Mining—Example Stressors, Sources, and Strategies

Potential Stressors

- ◆ Composition/structure alteration
- ◆ Flow and water level alteration
- ◆ Destruction, conversion, fragmentation, or disturbance of habitat
- ◆ Resource depletion
- ◆ Toxins (metals and other chemicals)
- ◆ Sedimentation
- ◆ Public health risks

Potential Sources

- ◆ Incompatible mining practices
- ◆ Inactive or abandoned mines

Potential Strategies (BMPs)¹

- ◆ Diversion ditches
- ◆ Mine waste rock/tailings removal and consolidation
- ◆ Stream diversion²
- ◆ Erosion control
- ◆ Capping
- ◆ Revegetation
- ◆ Aeration and settling ponds
- ◆ Sulfate-reducing wetlands
- ◆ Oxidation wetlands
- ◆ Other treatment methods

¹Some mining operations meet the legal definition of a point source and are subject to NPDES permit requirements. Colorado requires its active mines to have discharge permits.

²Projects involving stream diversions are subject to the U.S Army Corps of Engineers' CWA section 404 permitting requirements and WQCD CWA section 401 water quality certification.

remains uncontaminated from the mine material. Diversion ditches can also be used to intercept shallow groundwater that may enter a mine waste or mill tailings pile. DRMS emphasizes the importance of monitoring above and below the waste piles before constructing ditches to ensure that water quality is being degraded by moving through the piles. Costs to construct vary and are largely based on size of ditches and equipment needed to build. Maintenance involves periodically cleaning the ditches of debris and inspecting them for changes in slope bottom or erosion along ditch walls. DRMS recommends inspections before and after spring runoff and after major storm events.

4.10.1.2 Mine Waste Rock/Tailings Removal and Consolidation

This BMP involves the actual movement of the mine material away from water sources to minimize the chances for creating contaminated runoff. It is useful to consolidate piles if there are many small ones on the site. Key to the use of this BMP is the availability of an adequately large, dry and safe area in which to place the material and only reasonable amounts of mine wastes to be moved. Caps and berms or dams are built to hold the material. The costs to install this BMP vary depending on amount of material to be moved and distance to new site. Maintenance involves periodic inspections of the caps and berms or dams for erosion and to promptly repair any problems found.

4.10.1.3 Stream Diversions

This BMP involves diverting the waterbody away from and around waste rock and mill tailings. The strategy is to minimize water flowing through and over the mine waste to minimize contaminants getting into the water resource. This BMP can be extensive in terms of excavation. The previous two BMPs are preferable if they are an option. In this BMP, a new route for the stream must be excavated with adequate slope. The new banks also must typically be stabilized with riprap, a berm or heavy plantings. During high flow events, streams have a tendency to return to their original configurations. Costs for this BMP vary depending on the extent to which the stream must be rerouted. Maintenance involves inspections to ensure the stream is remaining in its new configuration. Repairs to stabilization systems should be made as identified. DRMS also recommends monitoring of the points of drainage from the waste rock or tailings to verify that they are decreasing over time. If not, that could mean there is a buried spring and another type of BMP would be required.

4.10.1.4 Erosion Control by Regrading

This BMP involves creating gently sloping surfaces to the stream that are filled with natural debris such as tree trunks and stumps. The erosion control measures are applied to the waste rock and tailings piles directly. The BMP is feasible if the mine material is not too toxic and can support vegetation. If the material will not support vegetation, it can be capped (see below). This BMP can be costly depending on the scale of the excavation and heavy equipment needed. As with the other BMPs, periodic inspections should be performed to ensure water is not pooling anywhere on the slopes. Any holes or pits should be repaired promptly.

4.10.1.5 Capping

This BMP involves adding layers of soil to waste rock piles and mill tailings. The soil layer is graded to reduce runoff. Vegetation is then added to protect the cap from erosion. Caps range

from simple to complex. A simple layer consists of approximately 6 inches of uncontaminated soil from the project site. A composite layer has at least two layers of different soil types. The layer closest to the rock pile or mill tailings is fine-grained and has low permeability to minimize water from seeping into the piles and forming acid drainage. The upper layer is coarser and is intended to support vegetation. A complex cap would involve the installation of interlayered synthetic filter fabrics and fine and coarse materials. The purpose is to inhibit water from coming into contact with the rock pile or mill tailings and to support vegetation on the top. Fencing is recommended if burrowing animals are known to inhabit the site. Steps to minimize erosion of the caps is necessary. Costs for this BMP vary by site location, type of capping material used, and equipment needed. Periodic inspections and repairs are necessary with this BMP as with the others.

4.10.1.6 Vegetation

The purpose of adding vegetation to waste rock piles and mill tailings is to help with erosion and reduce the amount of water that can infiltrate the pile. Secondary benefits of the BMP include the creation of habitat and addition of nutrients to the soil. Vegetation is often combined with other BMPs. The plant materials used should consist of native vegetation and be appropriate for the site and climate. Steps to minimize erosion from wind and water are useful to retain seed stock. The costs to implement this BMP vary based on acreage being vegetated. Maintenance involves periodic inspections and making adjustments in non-growth areas, such as further minimizing erosion potential.

4.10.2 Passive Treatment Strategies for Addressing Acid Mine Drainage

4.10.2.1 Aeration and Settling Ponds

Aeration settling ponds are preceded by routing wastewaters through several drop structures to create turbulence before draining to a settling pond with a minimum retention time of 24 hours. The turbulence increases the oxygen content of the water. The metals will drop out in the settling pond. This treatment works best with wastewaters that have a pH of 7 or more and high total suspended solids concentrations.

This BMP involves routing clean, high-pH water into settling ponds with acid mine drainage in order to raise the pH and precipitate some metals. The BMP is effective for iron, aluminum, copper, cadmium, and lead, and is slightly effective for zinc and manganese. The costs to install this BMP will vary depending on the depth of soil cover and the topography of the site. Maintenance involves periodic inspections of the aeration channels and drop structures and repairs of any problems. Maintenance also involves periodic removals of the sediment that has collected in the settling ponds. The sediment must be disposed in an environmentally friendly manner. Disposal options have varying costs.

4.10.2.2 Sulfate-reducing Wetlands

Sulfate-reducing bacteria reduce sulfates to sulfides, which form metal precipitates that settle in the bottom of the constructed wetland. The bacteria derive their energy from carbon. The constructed wetland is composed of a 3- to 6-foot layer of carbon source (e.g., cow manure,

mushroom compost, or sawdust) with a geotextile fabric filter separating the carbon layer from an underlying gravel bed. The constructed wetland might need to be lined below the gravel bed. The wastewater is discharged on top of the carbon bed and drains to the gravel layer. The treated effluent is discharged through a riser pipe from the gravel bed. If properly sized, the wetland can have a service life of 20–30 years. The metal-bearing residue may be disposed of or possibly, depending on the concentration, sold for processing.

The costs for installing this BMP depend on the size of the wetland and the cost of the substrate materials to be obtained and delivered. Maintenance involves removing sludge from the wetland (after 20–30 years) and ensuring its proper disposal.

4.10.2.3 Oxidation Wetlands

Metals such as iron, manganese, and arsenic are precipitated through oxidation by aquatic plants and algae. This BMP is applicable to wastewaters with a pH of 6.5 or higher. The wetland should be constructed so as to have shallow (10-inch) and deep (20-inch) depths, and the water should move through the wetland at a low velocity. Approximately 200 to 900 square feet of space is required to treat a flow of 1 gallon per minute. Wetlands should be planted with cattails, bulrushes, sedges, and rushes, in clumps about 1 foot apart. Oxidation wetlands are not efficient in the winter months. Oxidation wetlands, which resemble natural wetlands, may also attract waterfowl and other wildlife. The costs to install this BMP vary depending on the size of the wetland, materials used, and equipment needed. Maintenance involves periodic inspections to ensure proper flow. Any channelization of water should be addressed. Sludge will need to be removed after 20–30 years and disposed of in an environmentally acceptable manner.

4.10.2.4 Other Treatment Methods

Other treatment BMPs recommended by DRMS include the following:

- ◆ **Diversion of surface waters.** This BMP involves diverting clean water that may be entering the mine site where it could come in contact with sulfide bearing materials and result in acid mine drainage.
- ◆ **Dilution.** Clean water is mixed with acidic mine drainage in a settling pond where the resultant increased pH causes some of the metals to precipitate. The method is most effective in removing iron, aluminum, copper, cadmium and lead. It has only a slight effectiveness for manganese and zinc.
- ◆ **Land application.** Mine discharge is spread over a large area to infiltrate into thick soils. The natural processes in soils and subsoils (plant uptake, evaporation and transpiration and soil exchange capacity) combine with and remove metals.
- ◆ **Bulkhead seals.** This BMP is used to control the formation of acid mine drainage inside a mine. They are installed in an adit to prevent discharge to a nearby portal. The workings of the mine flood behind the seal. Seals are expensive and involve considerable geologic and engineering assessments.
- ◆ **Anoxic Limestone Drains.** Acid mine drainage is channeled through a buried trench containing chunks of limestone. The limestone dissolves and reduces the acidity. The waters drain to a settling pond, where the metals precipitate and settle out.

- ◆ **Aqueous lime injection.** This BMP involves passing clean water through a pond containing a high pH material (often lime). The high pH water (alkaline) is then mixed with mine drainage and is then discharged into a settling pond where the metals precipitate out.
- ◆ **Mechanical injection of neutralizing agents.** This BMP is used to treat acidic drainage from mine openings. A mechanical feeder (solar, wind or hydro-powered) continuously feeds a neutralizing agent (e.g., finely ground limestone) into the mine drainage. A settling pond is needed to enable the metals to precipitate out of the solution.

For the purposes of nonpoint source management funding, *inactive mines* are defined as mines that have not operated since passage of the 1972 CWA. Nonpoint source grant funding may be used to implement measures that do not require a point source discharge permit. These measures may include source controls such as moving tailings out of streambeds or riparian areas, capping and re-vegetating tailing piles, and diverting clean water around waste piles. DRMS conducted a successful pilot-scale project, demonstrating how separating clean water inflows from contaminated ores or wastes can significantly reduce the volume of mine drainage requiring treatment.

The DRMS conducted an extensive underground flow assessment using dye testing, physical inspection, review of historical work records, and other means to characterize the inflow and outflow in one level of the Mary Murphy Mill ruins. As a result, DRMS was able to identify one flow that accounted for 85% of the metals loading but only 1.5% of the total discharge volume. An earthen diversion structure was constructed to segregate the low-volume, high-concentration waste stream from the clean water inflow. As a result, the zinc concentration in the discharge was reduced from 5,000 micrograms per liter ($\mu\text{g/L}$) to 250 $\mu\text{g/L}$. This project was completed in 1998 and was partially funded with CWA section 319 grant funds (USEPA N.d.).

Source control measures such as those used in the Mary Murphy Mine project might not be feasible if the mine is unstable and not safe to enter. Also, many mines are in remote areas that might not have ready access to utilities. In such instances, passive remediation methods might be the most feasible alternative for addressing mine drainage.

4.11 Strategies with Wide-Ranging Applicability to Stressors and Sources

4.11.1 Monitoring

The term “monitoring” in the water quality arena generally pertains to quantitative and qualitative assessments of the biological, chemical, physical, and radiological integrity of various water resources. Monitoring is undertaken to establish baseline conditions and to measure changes in condition over time. Monitoring data help researchers identify and characterize stressors and sources. They also provide a means for watershed managers and practitioners to evaluate the effectiveness of their protection and control strategies. This information feeds back into the overall restoration and protection vision for the watershed.

4.11.2 Permitting

The CWA requires that all point source dischargers must have a NPDES permit if they are to discharge wastewater to waters of the United States. Under state authorities, discharge permits are required for point source discharges to waters of the state. The NPDES permit establishes technology-based effluent limitations and/or water quality-based effluent limitations (i.e., limitations necessary to ensure that the discharge will not cause or contribute to an impairment of water quality standards). Industrial discharges to sanitary sewers are subject to pretreatment requirements to reduce toxic and other chemicals from their wastes before discharging them to the municipal wastewater treatment plant.

The CWA establishes permitting as a strategy for minimizing pollutants from being discharged to surface waters from point sources. In EPA's *2006–2011 EPA Strategic Plan: Charting Our Course*, the goals for the NPDES permitting program included the following (USEPA 2006):

- ◆ Address concerns about the backlog in issuing NPDES permits.
- ◆ Support the use of innovative permitting tools for watershed based permitting and pollutant trading.
- ◆ Ensure that NPDES permits for storm water discharges resulting from industry, construction, and MS4s are promptly reissued when they expire.
- ◆ Ensure that industrial discharges to municipal wastewater treatment plants are pretreated effectively.
- ◆ Promptly issue NPDES permits for CAFOs with required nutrient management plans.

The EPA *National Water Program Guidance* for fiscal year 2011 expands on many of the goals in the *2006–2011 Strategic Plan*. The guidance emphasizes the goal of developing TMDLs (see next subsection) and NPDES permits that more effectively address water quality problems. Strategies include the following:

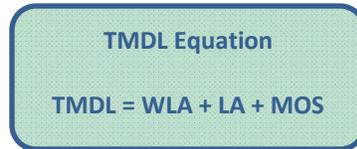
- ◆ Integrating the permitting and enforcement oversight to address the most significant water quality problems.
- ◆ Identifying high-priority permits based on programmatic or environmental significance and committing to issuing a specific number of those permits during the fiscal year.
- ◆ Organizing TMDLs to address all impairments within the watershed.
- ◆ Organizing permits on a watershed basis to facilitate cost-effective pollution reductions through water quality trading.
- ◆ Ensuring that all CAFOs are covered under an NPDES permit.
- ◆ Working with states to set targets for the percentage of NPDES permits that are considered current, with a minimum target of not less than 90% of permits being current.

4.11.3 TMDLs

CWA section 303(d) requires states to periodically submit to EPA a list of waterbodies that are impaired, meaning that the segment is not meeting the standards for its assigned use classification. The list of impaired waterbodies is referred to as the CWA section 303(d) list. The

WQCD prepares the list in conjunction with its biennial Integrated Reports.⁸ The WQCC approves and adopts the list as Regulation No. 93: *Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List* (5 CCR 1002-93) (WQCD 2010b; WQCC 2010b).

TMDLs must be developed for waterbodies on the CWA section 303(d) list. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still maintain water quality standards. The TMDL is the sum of the waste load allocation (WLA), which is the load from point source discharges; the load allocation (LA), which is the load attributed to natural background and/or nonpoint sources; and a Margin of Safety (MOS).



TMDL Equation

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

TMDLs are a further strategy for addressing water quality problems in watersheds. Their effectiveness depends on the degree to which the WLAs and LAs are implemented. EPA and CWA-authorized states have authority to require implementation of WLAs on point sources, but they do not have authority to require nonpoint sources to meet LAs. Instead, EPA and the states must develop and implement strategies appropriate to nonpoint sources to achieve LAs. Other stakeholders in watershed protection activities often have greater leverage or ability than regulatory agencies to encourage voluntary actions on the part of nonpoint sources. Local watershed organizations developing watershed protection plans should consider including strategies for WLA and LA implementation by point and nonpoint sources, respectively, to the extent the TMDLs address parameters of concern to the group.

4.11.4 Compliance Assurance

When Congress first passed the CWA, it established two national goals. The first was to eliminate the discharge of pollutants into the navigable waters of the United States by 1985, and the second was to establish an interim level of water quality that provides for the protection of fish, shellfish, and wildlife and recreation by July 1, 1983 (USEPA 1972). These goals have yet to be fully realized.

On July 2, 2009, EPA Administrator Lisa Jackson issued a memorandum directing Cynthia Giles, the Assistant Administrator for EPA's Office of Enforcement and Compliance Assurance, to work with the Office of Water to develop an action plan (Jackson 2009). The result of this directive was EPA's Clean Water Enforcement Action Plan, which was later renamed the Clean Water Action Plan. Enforcement and compliance activities are strategies for ensuring that regulatory requirements aimed at protecting water quality are implemented.

The key elements of the Clean Water Action Plan are to:

- 1. Target enforcement to the most important water pollution problems.** The need for targeted enforcement is apparent considering that the number of regulated point source dischargers has expanded from 100,000 traditional point sources to nearly 1 million more dispersed sources, such as CAFOs and stormwater discharges.

⁸ WQCD's latest report is called the *2010 Integrated Water Quality Monitoring and Assessment Report* (WQCD 2010).

2. **Strengthen oversight of the states, where needed, to ensure consistent enforcement across the nation.** This element is necessary to ensure equal protection of water quality and public health across the nation and to ensure that businesses do not realize a competitive advantage by operating in a state with a lax enforcement program.
3. **Improve transparency and accountability.** The public and the regulated community have a right to know what the threats to water quality are, where violations are occurring, and what the regulatory agencies are doing about them.

The Clean Water Action Plan has identified CAFOs and stormwater discharges as areas requiring targeted enforcement. EPA's Office of Enforcement and Compliance Assurance has made CAFOs a CWA priority for monitoring, compliance assistance, and enforcement through FY 2010 (USEPA 2009a). This is likely to affect Colorado, which is one of the largest beef-producing states in the country.

4.11.5 Sustainable Water and Wastewater Point Source Infrastructure

EPA has defined *sustainability* as meeting today's needs without compromising the ability of future generations to meet their needs. The U.S. population today enjoys very low water and wastewater utility fees as compared to the rest of the developed world. This is due in part to the fact that most of the infrastructure was built nearly 30 years ago. Rates will increase substantially to pay for the replacement of aging infrastructure. To maintain a sustainable rate structure, it will be necessary to economize in other areas of utility management. EPA's four pillars of sustainable management are (1) better management designed to reduce cost, (2) full-cost pricing to avoid subsidizing current rate payers, (3) water conservation, and (4) using watershed approaches to look at water quality in a coordinated way. A brief summary of sustainable measures for operating water and wastewater utilities is provided in exhibit 4-3. For more information, go to <http://www.epa.gov/ednrmrml/models/sustain/index.html>.

Ten Attributes of Effective Utilities

1. Product quality
2. Employee and leadership development
3. Financial viability
4. Community sustainability
5. Stakeholder understanding and support
6. Customer satisfaction
7. Operational optimization
8. Operational resiliency
9. Infrastructure stability
10. Water resource adequacy

4.11.6 Infrastructure Planning for Global Climate Change

When planning and designing upgrades to municipal wastewater and stormwater conveyances and wastewater treatment facilities, municipalities are encouraged to consider the potential impacts of climate change. Although it is generally agreed that there is still a high degree of uncertainty in the global climate models, analyses of long-term data sets indicate certain trends. These trends might impact sizing criteria used for designing sewage and stormwater conveyances and BMPs, as well as the selection of treatment systems that might be needed to meet more stringent water quality-based effluent limits.

Exhibit 4-3. Strategies to Achieve Sustainable Infrastructure

Better Management. EPA worked collaboratively with water and wastewater utilities across the country to develop a management system and tools for developing sustainable water utility organizations. This initial effort culminated in a report entitled *Effective Utility Management, A Primer for Water and Wastewater Utilities*. The report lays out a systematic approach to identifying and achieving key attributes of an effective utility. See EPA's website for a copy of the Primer and other resource tools at <http://water.epa.gov/infrastructure/sustain/watereum.cfm>.

- ◆ **Asset Management.** An effective asset management plan can prolong the life and stability of the infrastructure, thereby contributing to financial viability, customer satisfaction, and operational resiliency—4 of the 10 attributes of effective utilities. An effective asset management plan includes a proactive operations and maintenance and capital replacement plan based on long-range planning, life-cycle costing, and cost-benefit analysis. EPA provides support materials for developing an effective asset management plan, including the Checkup Program for Small Systems (CUPSS) software program. The software assists the user in recording assets, scheduling maintenance and replacement, understanding its financial standing, and developing a tailored asset management system. For more information, see the EPA webpage at <http://water.epa.gov/type/watersheds/wastewater/index.cfm>.
- ◆ **Environmental Management System (EMS).** EPA is providing support to water and wastewater utilities to implement EMS ISO 14001 into their management systems. EMS incorporates consideration of impacts on the environment into everyday operations and decision-making throughout the organization. Working with the Global Environment and Technology Foundation, EPA has compiled and provided tools and information for developing EMS systems. See the following EPA webpage for more information: <http://water.epa.gov/polwaste/wastewater/Voluntary-EMS-ISO-14001.cfm>.

Energy Efficiency and Renewable Energy Opportunities. Energy Efficiency. Energy conservation at wastewater treatment facilities reduces greenhouse gas emissions and operating costs. Energy conservation can be a key element in the utility's cost and EMS management programs. Municipalities can improve the energy efficiency of their wastewater and water utilities through a management systems approach. EPA's *Energy Management Guidebook for Wastewater and Water Utilities* is a guide to energy conservation. It provides a step-by-step approach for conducting energy audits, setting energy reduction goals, prioritizing projects, gaining internal support, and measuring success. It also provides links to several useful tools and databases, including the Energy Star Benchmarking Tool and the Energy Star Profile Manager. A companion manual, *Water and Wastewater Energy Best Management Practice Guidebook*, provides BMPs that can be used to achieve energy reduction goals. Both manuals can be accessed at <http://water.epa.gov/infrastructure/sustain/energyefficiency.cfm>.

Renewable Energy. Combined Heat and Power (CHP) is an option for wastewater treatment facilities that have, or are planning to install, anaerobic digesters. Generally, CHP systems are cost-effective for facilities with an influent of 5 million gallons per day or greater (ERG and EEA 2007). CHP systems reduce greenhouse gas emissions and might be subject to future carbon offset credits, as described in the Colorado Climate Action Plan. The biogas flow from the digester can be used as free fuel to generate electricity and power in a CHP system using a turbine, micro-turbine, fuel cell, or reciprocating engine. The thermal energy produced by the CHP system is then typically used to meet digester heat loads and for space heating. A well-designed CHP system offers the following benefits:

- ◆ Reduces greenhouse gas and other air emissions
- ◆ Provides possible opportunities for carbon offset credits if future carbon banks or trading markets are established
- ◆ Produces power at a cost below that of retail electricity
- ◆ Displaces purchased fuels for thermal needs.

Full-Cost Pricing. Full-cost pricing is a method to fully recover the cost of water, water conveyance, and treatment and to promote water conservation. EPA recommends a number of pricing strategies to reflect the cost of delivered water and to discourage excessive water use. These strategies include tiered pricing, with higher rates for higher usage, surcharges for excessive use, higher prices for water delivered during high-demand periods, and seasonal pricing to reflect changes in demand and supply. The EPA website also provides guidelines for considering affordability and other price considerations, as well as information on available State Revolving Funds and other funding sources; see <http://water.epa.gov/infrastructure/sustain/about.cfm>.

Water Conservation. Water conservation reduces the stress on the nation's drinking water supplies and the natural systems that also depend on those supplies. Conservation can reduce the amount of water diverted from surface waters and thereby preserve their assimilative capacity and ability to support the aquatic life classified use. Water treatment and delivery to residential, commercial, and industrial users consumes energy, and therefore water conservation also reduces energy use. EPA supports water conservation through its WaterSense program. EPA approves the WaterSense label for products that conserve water without sacrificing performance. The Agency also supports the Alliance for Water Efficiency, a clearinghouse and advocate for water efficiency, research, evaluation, and education. See EPA's website for more information: <http://water.epa.gov/infrastructure/sustain/index.cfm>.

Some of the changes that have occurred or are expected to occur because of climate change include the following:

- ◆ An increase in the frequency of intense rainfall and peak flows.

- ❖ Reductions in storm return frequency used to size conveyances and BMPs. (For example, what used to be a 100-year storm might now be a 60-year storm.)
- ❖ Increased scour and undercutting of stream banks and changes in stream morphology.
- ♣ Reductions in groundwater recharge due to more frequent and prolonged drought, reduced snowpack, and rainfall occurring in more short, intense storms; changes in stream morphology; and changes in vegetative cover (e.g., the loss of trees due to insect infestations and the increased number and intensity of wildfires).
- ♣ Reductions in base flow due to increased and more prolonged drought, reduction in alluvial groundwater discharge, and increased evaporation caused by increased temperatures and reduced riparian canopy cover.
- ♣ Reductions in the 7Q10 low flow statistic used to calculate some water quality-based effluent limitations and TMDLs, resulting in more stringent effluent limits, as well as lower WLAs and LAs. (The 7Q10 is the 7-day, consecutive flow with a 10-year return frequency.)
- ♣ Earlier snowmelt, resulting in earlier flooding, but not necessarily an increase in floodwater volume (USGS 2009).
- ♣ Decreased dissolved oxygen levels due to increased water temperatures, which may be exacerbated by increased nutrient levels.

A recent statistical analysis of precipitation extremes by Arthur T. DeGaetano indicates that in general, the storm return level in the United States is decreasing by approximately 0.75% per year. That means that what was considered a 100-year storm in 1950 would be a 60-year storm in 2009 (DeGaetano 2009 as cited in O'Neill 2010). Because stormwater infrastructure is normally designed for a 30-year or longer life span, engineers should consider accounting for the change in storm return levels or risk that the facilities will be undersized in their later years. Likewise, more intense rainfall will cause more infiltration into sanitary sewers and increase the potential for sanitary sewer overflows. Engineers should consider the trend in increasing storm intensity when designing sewers and storage for peak flows, as well as operational changes to eliminate sanitary sewer overflows based on local hydrology data. O'Neill recommends that engineers evaluate local rainfall data using partial-series maximum precipitation techniques to evaluate trends and to review local climate model predictions (O'Neill 2010).

A reduction in the base flow of receiving waters will result in more stringent water quality-based effluent limits and might require more advanced treatment at municipal wastewater treatment facilities and improved stormwater and nonpoint source controls. Dissolved oxygen impairments will become more pervasive if instream water temperatures increase, as is expected. Dissolved oxygen levels might also be further depressed if nutrient concentrations increase as a result of decreased base flow or increased nutrient loading.

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